

# Caves in Basalts in Krông Nô Area, Đắk Nông Province, Vietnam

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**Abstract:** Caves have always been creating a mysterious and fascinating beauty for geoheritages, natural heritages, as well as geoparks. Caves in sedimentary rocks, especially in karst in Vietnam are diverse, often breaking new records in length, depth and distribution region wide and world wide. Meanwhile, caves in basaltic rocks in Vietnam were discovered in 2007 in the area of Trinh Nữ waterfall, Krông Nô District, Đắk Nông province. The Trinh Nữ waterfall area is an attractive heritage complex on both natural and socio-cultural aspects. It comprises 3 waterfalls and the famous associated scenery in the Central Highlands, the craters, columnar basalts, resurgences of underground springs, primary forests, national historic cultural monuments, etc. Caves here are quite numerous and usually extend in certain direction. Classified by depth and water table, caves exist in 2 types: dry caves and wet caves. A majority of caves are 3-6m in diameter, some of which are up to over 10m with the length of several hundred meters. On the walls and ceilings of quite a few caves, turbulent flows of lava are clearly observed. A majority of caves are homes of many bats. The caves inner area certainly has much potentials for exploration in the disciplines of archeology, biology as well as geology. The cave system here will make a rich and unique geoheritage area of Trinh Nữ waterfalls, and will also be the tourism highlight provided that it is to be researched, restored and put available to geotourism.

**Keywords:** Cave - Basalt - Heritage.

## 1. Introduction

60% of Vietnam territory is covered by sedimentary rocks, and almost 20% is limestone. Limestone in Vietnam is mainly Pre-Cambrian (550 million years) to Middle Triassic (about 235 million years ago) of age.

Most limestone is concentrated in the North, and even occupies about 50% of the total area of some provinces such as Hoa Binh (53.4%), Cao Bang (49.47%), and Tuyen Quang (49.92%). Many towns and villages lie entirely on limestone, such as Mai Chau (Hoa Binh province), Moc Chau, Yen Chau, Son La (Son La province), Tua Chua, Tam Duong, (Lai Chau Province), Dong Van, Meo Vac (Ha

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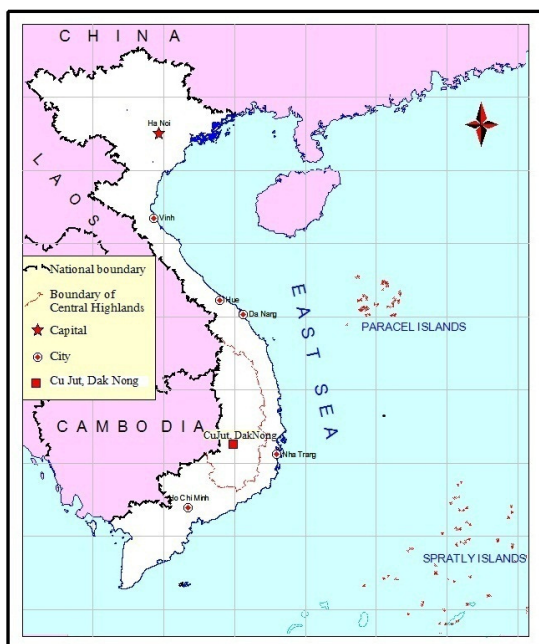


Fig. 1 Distribution area of caves in basalts in Krong No area, Dak Nong, Vietnam.

Giang Province), etc. [1]. A minority of limestone distributes in the Southern of Vietnam such as Ha Tien (Kien Giang). Most of localities on limestone possess quite a few number of caves. Each cave has its own beauty, and is often associated with a fascinating legend to attract people to visit, discover and enjoy. Caves in limestone in Vietnam are diverse, often breaking new records in length, depth and distribution in the region and the world. Among them must be mentioned cave Son Doong (discovered by a local in 1990), which has been studied in details since 2009-2010 in the project namely “Cooperation project of speleological research in Vietnam” by the Department of Geography, University of Natural Sciences (VNU-HUS) and the British Cave Research Association. Son Doong cave lies within the Phong Nha – Ke Bang World Heritage Assemblage in Quang Binh Province. It is



Fig. 2. Chu Pluk crater at Choah village. (Source: La The Phuc, 2012)

mentioned as a "majestic and surprisingly beautiful cave, with so many stalactites of strange shapes; ... there's a jungle inside Vietnam's mammoth cavern. A skyscraper could fit too. And the end is out of sight" - that is the evaluation of the cave Son Doong from the famous magazine National Geographic. In the report of “Vietnam 2012”, the British Cave Research Association recognized Son Doong as the world's largest arch. The cave is 200-250m in width, over 150-200m in height and 8.57km in length [2].

In addition to the mysterious beauty, cave system in Vietnam also possesses the natural heritages (biodiversity, genetic resources of rare animals and plants, etc.) and archaeological sites. Some of them are endangered species recorded in the Red Book of Vietnam in 2007, such as: Anh Vu fish (*Semilabeo obscurus* (Lin, 1981)), Chien fish (*Bagarius*), which live in the caves and subterranean rivers in Tuyen Quang, Phu Tho, and Ha Giang provinces.



Fig. 3. Dray Sap waterfall. (Source: La The Phuc, 2007)



Fig. 4. Pure lake flowing from basaltic cave right next to Gia Long waterfall (Source: La The Phuc, 2009).

Some other representatives are Mo Khe Lanh fish (*Lobocheilos* sp.), which is an endemic species that only exists in Khe Lanh of Phong Nha – Ke Bang World Natural Heritage, flower ratsnake (*Orthriophis moellendorffii* (Boettger, 1886)), living in caves resided by a large number of bats in Tuyen Quang, Bac Kan, Lang Son, Thai Nguyen, Ninh Binh, Nghe An, Ha Tinh, Quang Binh, Quang Tri provinces, etc. Archaeologists have found many relics of the teeth of the Homo erectus people (upright man) dating 250,000 - 140,000 years and other animals' bones, all of which have been petrified and lay in the middle Pleistocene sedimentary layer at Tham Khuyen cave, Tham Hai of Tan Van commune, Binh Gia district, Lang Son province (www.baotanglichsu.vn dated 07/6/2012). These traces show that Vietnam is one of the places where people have lived since a quite early time.

In addition to the famous caves in limestone, there is a unique cave system developed in basaltic rocks. Basalt in Vietnam is plentiful and varied, aged from Paleozoic to Cenozoic, mainly distributed in the North, Central and Central Highlands of Vietnam (latitude  $10^{\circ}25' \div 23^{\circ}00'$ ), and is located the most in the Central Highlands. The Central Highlands of Vietnam is also known as the red-



Fig. 5. Bats flying out of one cave in Krong No (Source: La The Phuc, 2009)

soil plateau, basaltic highland, including 5 provinces: Kon Tum, Gia Lai, Dak Lak, Dak Nong and Lam Dong. Caves in basalts in Vietnam have only been discovered since 2007 in Dray Sap - Choah Village waterfall area within Trinh Nu waterfall heritage assemblage, Krong No district, Dak Nong province (Fig 1). Since then, the caves here have not been examined in details regarding related issues. There are still many mysteries yet to be discovered.

## 2. The research methods conducted in caves in basalts in Krong No, Dak Nong

The Pliocene – Quaternary eruptional activity in Central Highlands is quite plentiful and diverse, which has made up many spectacular geoheritages, serving well for tourism development. In the scope of the



Fig. 6 Ceiling collapse of shallow cave in Choah Village (Source: La The Phuc, 2012).

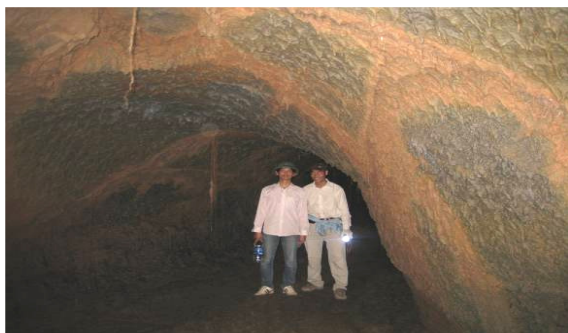


Fig. 7. Interior scene of one bat cave in Krong No.  
(Source : La The Phuc, 2012)

project "Geoheritage investigation for the establishment of geomark and environmental protection in Trinh Nu waterfall area, Krong No Area, Dak Nong province, Vietnam" and the project "Overall study and assessment of tourism resources, spatial planning and proposal of tourism development solutions in Central Highlands", coded TN3/T18, the authors have only used the methods for preliminary study. They are:

### 2.1. Methods of inheritance

Collecting, synthesizing materials of basic geological surveys in different ratios; thematic research on magma (including basalt eruptions); studies on geomorphology and existing geoheritage in the study area. This is the traditional method of geoscience research. On the basis of the collected data, the research will be planned and conducted.

### 2.2. Field survey methods

On the basis of the collected material, the author has conducted a field survey to examine and collect the original document (the actual document), do photoshoot or record videos, set the values of geoheritages, etc. as the scientific basis for the evaluation, establishment, classification of geoheritages and the assessment of geoheritage and geotourism



Fig. 8. Stalactites in Bat cave, Krong No, Dak Nong  
(Source: Truong Quang Quy, 2012)

resources; as well as propose solutions for the conservation, management and exploitation towards the sustainable development.

### 2.3. Methods of heritage statistics and classification

On the basis of the field survey, the geoheritages of the study area will be fully established, documented and classified according to the UNESCO criteria (GILGES system).

### 2.4. Methods of assessment and ranking

In the heritage dossier, the geoheritages are assessed in such criteria as: outstanding values in science, education and aesthetics, area of distribution, safety level of heritage to natural and social impacts, level of convenience regarding transportation, community and organization of services when the heritage has been recognized and put into operation, prospect of conceived benefits when the heritage is protected and exploited. On the basis of the

dossier, the geoheritages shall be ranked, classified and requested for appraisal.

### 3. Preliminary research results of the distribution area of caves in basalt rocks in Krong No, Dak Nong

Geological mapping results in different scales show that basalts in Dak Nong Province in general and in Krong No Area in particular belong to two different formations: Tuc Trung and Xuan Loc formations. Basalts of Tuc Trung formation are of Pliocene – early Pleistocene (B/N<sub>2</sub>-Q<sub>1</sub> *tt*) age (5.3÷1.6 m.y.a). The lithological composition is mainly alkali olivine basalt, olivine-augit-plagioclase basalt, basalt 2 pyroxene.

The rocks are black gray, mainly dense with minor porosity, porphyritic texture with phenocryst being olivine (10÷15%), augite (3÷4%); the background usually composes of plagioclase (40÷45%), olivine (4÷5%), augite (10÷20%). They are divided into two units: Unit 1: dense basalt intercalated with a small amount of fine to average-grained, gray to black gray porous basalt, thickness of about 42m.



Fig. 9. Turbulent flow on the wall of Bat cave (Source: La The Phuc, 2009).



Fig. 10. Surface of basaltic flow conserved in some samples in Bat cave (Source: Nguyen Thanh Tung, 2012)

Unit 3: medium-grained dense ash gray and dark gray olivine basalt, strongly cracked on the above, thickness of about 32m [3].

Basalts of Xuan Loc formation are of middle Pleistocene age (B/Q<sub>1</sub><sup>2</sup>*xl*) (about 781÷126 thousand years), and are divided into three units: Unit 1: brown gray to black volcanic ash, locally tuff alternating with layers of gray porous basalts, thickness of about 35m. Unit 2: original basalts include dark gray olivine basalt, dolerite basalt, plagiobasalt, quite uniformly blocky structured, thickness of 45÷50m. Unit 3: In addition to the eruptive lava, there are also explosive lava with the main composition of black, gray green olivine basalt. The rocks are densely structured, intercalated with pores, bubbles, volcanic bombs and volcanic breccias, thickness of 45÷51m [3].

The basalt eruptions have created the highly valued geoheritages. According to GILGES classification system of the UNESCO, the basalt eruption-related geoheritages have been established under the following categories: B-Geomorphology, D-Rocks, F-Minerals. Besides geoheritages, the study area also possesses historical and cultural monuments, forming a heritage complex within the distribution area of primary forest.

### 3.1. Category B-Geomorphology

Heritages under this category are the most common and abundant in the area, including: crater shapes, waterfalls and waterfall scenic landscapes and especially caves in basaltic rocks.

Crater in Choah village (namely Chu Pluk, Fig. 2) has shape of a funnel with diameter of about 100÷120m towards the top. A particular lava outlet is not visible. The lava dome was created with 600÷700m in width, and the volcanic throat is 100m in depth. The entire crater is light bubble basalts in pellets with many different shapes, but mostly isometric with diameters ranging from small to 30÷40 cm.

In the study area, there are three famous



Fig. 11. Traces in shape of tree branch on the wall of Bat cave (Source: Truong Quang Quy, 2012)



Fig. 12. Columnar basalts in Trinh Nu waterfall, Krong No, Dak Nong. (Source: La The Phuc, 2009)

beautiful waterfalls of the Central Highlands: Trinh Nu, Dray Sap and Gia Long waterfalls (Fig. 3). All of these 3 waterfalls flow on basalts and belong to Serepok river. Each waterfall is associated with a thrilling and romantic legend of ethnic groups in the Central Highlands. Besides the muddy waterfalls roaring all year long are the clear, calm and gently flowing springs and the peaceful blue lake (Fig. 4), which makes up a strangely-dreamy contrasting scene.

So far, in Trinh Nu – Dray Sap – Choah village areas, 10 pretty nice caves have been discovered. None of these caves have been adequately studied. What is interesting to visitors and striking for the researchers is that the caves develop in basalts rather than in carbonate (limestone) like most other caves in Vietnam.

The caves here have not been named, and the locals call them Bat caves, since there are a numerous number of bats living inside them (Fig. 5). We made efforts to enter some caves, do preliminary survey and took some photographs and videos. The preliminary survey results show that: the diameters of the cave entrances range from 5÷15m, the heights from the floor to the ceiling range from several to 10m, the average lengths are several hundreds meters (particularly some may reach several kilometers). The caves generally extend toward  $150^{\circ}\div 160^{\circ}$  and  $320^{\circ}\div 330^{\circ}$  directions, which create 2 systems extending nearly coincidingly with the NW-SE and NE-SW trending faults in the area. The caves usually branch horizontally, whereas there is no observed vertical branching. However, there are some narrow horizontal caves that need rope ladder to come down.

The caves distribute at depths of several to several tens of meters to the ground. They are composed of 2 types: dry caves and wet caves.. According to the distribution depth, dry caves are divided into 2 types: shallow caves and deep caves. Shallow caves are those having distribution depth of less than 5-6m from the ground, often with thin dome cover. This type of caves often occur the collapse of ceiling due to structural weakness (Fig. 6). Deep caves are those having distribution depth of more than 6m from the ground, with thick dome cover, quite sturdy and safe, can be exploited for tourism (Fig. 7). Wet caves are those with regular flows or constantly flooded. Caves of this type are generally small (with diameter of 1÷3m), distributing in low terrain of the area, may be at or below the water table. The cave entrances are exposed on the erosion cliffs and have flows of clear water all year long. These are the source of water for the springs and lakes of the area,

making a beautiful landscape in contrast with the muddy waterfalls (Fig. 4).

Rocks on the ceiling and the walls are gray-black gray dense basalts and pore basalts (lesser) of Xuan Loc formation, locally existing stalactites (Fig. 8). On the samples and walls there are observed phenomenon of turbulence flows of basaltic lava flows (Fig. 9, 10) and the remains of the woody branches with diameter of 20÷30 cm (Fig. 11). On the floor of some caves, traces of temporary flows, which may be the streams during the wet seasons, and pieces of animal bones are also found. Sometimes, the locals still get into the caves to hunt wild animals. These above geomorphological heritages are ranked national level geoheritages.

### 3.2. Category D-Rocks

Heritages of this category are columnar basalts, volcanic bombs and bubble basalts. Columnar basalts are typical heritage of Trinh Nu waterfall area under D category. Columnar basalt formation is associated mainly with Tuc Trung formation, composed of olivine-augite basalt and olivine basalt. The basalts are dense, rarely porous or almond; gray-black gray, columnar cracked with the number of sides ranging from 4÷5 or 6, whose area is 10÷15cm, rarely more than or equal to 20cm (Fig. 12), in which those with 6 sides are dominant. The largest diameters of the columns are about 30÷40cm, and the lengths are about 3÷6m. Besides, they are controlled by numerous fractures with no certain directions and lengths [4, 5]. These columnar basalts are requested to be ranked as national level geoheritage.

Volcanic bombs are found scatteredly in the valley of Choah village (Fig. 13). They are usually black gray, have large sizes with blocks reaching several  $m^3$ , and contain various pores



Fig. 13. Volcanic bombs in the valley of Choah village, at the back is Chu Pluk crater (Source: Nguyen Van Hiep, 2007)

which are now weathered [3]. In addition, associated with Chu Pluk volcano in Choah village, we also found various spongy gray-cement gray bubble basalts with porosity of 30÷40%. Those are puzzolan ores.

### 3.3. Category F-Minerals

Those under this category are olivine, opal-chalcedon, bauxite ore and puzzolan. In particular, olivine and opal - chalcedon are of little expression and value, so they are not considered potential. Puzzolan has formed deposit and is the most potential. The found puzzolan is directly associated with Chu Pluk volcano. The whole crater are pellets of lightly spongy bubble basalts in different shapes, but mostly isometric and are from small to 30÷40 cm in diameters. About 600÷1,000m from the crater are basalt flows that form into comparatively thick layer, which contains lightly spongy rocks with 30÷40% porosity. The basic chemical composition of the rocks achieved by analysis shows:  $\text{SiO}_2 = 49,92\div 51,86\%$ ;  $\text{Al}_2\text{O}_3 = 14,19\div 15,07\%$ ;  $\text{Fe}_2\text{O}_3 = 12,10\div 12,50\%$ ;  $\text{TiO}_2 = 1,44\div 1,60\%$ ;  $\text{CaO} = 7,25\div 10,88\%$ ;  $\text{MgO} = 8,16\div 9,35\%$ ;  $\text{LOI} = 1,60\div 2,18\%$ ; lime absorption level: 61.22÷76.29 (mgCaO/1g puzzolan). Total forecast resource is about 19,000,000 tons [3].

In addition to the potential for geoheritage as mentioned above, the caves in basalts also distribute in the assemblage of national and international leveled natural heritages, such as: Dray Sap Waterfall Cultural and Historical Monument (national level cultural monument as ranked in 1991 by the Ministry of Culture and Information), Gia Long Waterfall Cultural and Historical Monument (national level cultural monument as ranked in 1999 by the Ministry of Culture and Information), the Gong – Cultural Heritage of Central Highlands (World Cultural Heritage as ranked by the UNESCO in 2005), as well as the Dray Sap primary special-use forest along with its biodiversity (wildlife, insects, rich genetic resources) in the forest and in caves, which have not been studied in details.

## 4. Discussion

So far, caves in Vietnam mostly develop in carbonate rocks (limestone, argillaceous limestone, etc.), or lesser in terrigenous sedimentary rocks (sand, silt, clay). They are formed after the rock formation process due to the rock dissolution and erosion along the fracture system or the layer surface. Unlike other kinds of rocks, basalts are hard to dissolve making the formation of cave in basalts totally different. Caves in basalts are formed during the tubulent flows, air drainage and cooling down of lava. This is one of the distinctive characteristics of the discovered caves in Vietnam. In order for caves to form, the basaltic lava must have a relatively high viscosity. When erupted, the basaltic lava blows from the ground and flows by the terrain surface down to the lower areas in steep slopes. These slopes are usually sinuous, cross cutting or even perpendicular to the original lava flows. During



the blowing-flowing, together with the interaction of temperature - pressure of the lava with rocks and the external environment, the turbulent flows shall form, creating the spaces (air) inside the lava flows and ventilation occurs. As the basaltic lava has high viscosity (dense), and is rapidly cooled on the ground, the empty space and the bubbles could not release from lava blocks before the lava froze to form the cave as described above. So the caves here were formed at the same time of rock formation (syngenetic). The presence of caves in Krong No, Dak Nong (Central Highlands) is rare, especially when they are located in basalts. This is one of the "impression" to attract tourists to heritage assemblage in Krong No area. In addition to the values in landscape and aesthetics, caves in the study area are also destinations for scientists (in geology, archeology, biology) and students to explore and study on the mechanism of formation, composition and other scientific issues related to basalts in the Central Highlands, including the formation of caves in basalt rocks. Furthermore, they are also destinations for artists, photographers to enjoy and create.

The study area owns many beautiful landscapes with natural heritages (primary forest, geohéritages) and cultural heritages, which have been ranked. Natural heritages, geohéritages, especially the caves are still almost untapped and have not been studied in-depth for the ranking. At the adjacent areas of Krong No Area, many archeological sites have been found (working tools and tool manufacturer). So, if the caves are studied in details, it is certain that archeological sites as well as other endemic creatures will be found. So, the study area has comparatively fulfilled the requirements to establish geoparks as per criteria set by the UNESCO.

With the huge potential of such heritages, if the protection, management and exploitation are well organized, this place will be an attractive destination for picnic, geotourism, ecotourism, study and geological research, which contributes to the training, raising community awareness, socio-economic development of the area as well as the whole country.

Studies on geohéritage towards conservation and sustainable development are relatively new in Vietnam. So far, the Vietnamese geologists have employed a quite good approach; moreover, they have compiled dossiers and recognized by the UNESCO for 2 World Natural Heritage (Ha Long Bay and Phong Nha – Ke Bang), 1 Global Geopark (Dong Van Karst Plateau). In the future, there will be more potential candidates to achieve the title. Besides the very encouraging study results, because Vietnam's economic conditions are still difficult, investment in this research field is very limited. Most of the geohéritages in the Central Highlands and islands of Vietnam have not been examined in details. The legal system related to the conservation, classification, management and exploitation of geohéritage has not been established. To address that, Vietnam plans to get attention of scientists as well as scientific research institutions, foreign investors for the research, conservation and sustainable exploitation of geohéritage in Vietnam.

## **5. Conclusions and recommendations**

- The existence of caves in basalts in Krong No is one of the impression to diversify the heritage assemblage in the area.
- Caves in basalts in Krong No are common, original and of high values from both

scientific and practical perspectives, particularly for research and tourism purposes.

- Krong No area and its vicinity (Dak Nong and Dak Lak provinces) relatively fulfill the natural elements to build national geopark, and are potential candidates for an international geopark.

- Geoheritage in general and caves in basalts in particular in Krong No, Dak Nong should be studied in details to clarify issues on scientific and educational significance of the heritage, the structure of the heritages, especially, the structure of the caves and archaeological-paleontological sites in the caves... to compile the dossier for the establishment of geopark, contributing to the conservation, management and rational exploitation of geoheritages towards the socio-economic sustainable development.

- Vietnam is a developing and integrating country, which needs collaboration from more developed ones to share relevant experiences and research works in the field of conservation,

management and sustainable exploitation of geoheritages.

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## Hang động trong đá bazan ở khu vực Krông Nô, tỉnh Đắk Nông, Việt Nam

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**Tóm tắt:** Hang động luôn tạo ra vẻ đẹp huyền bí và hấp dẫn cho các di sản địa học, di sản thiên nhiên, cũng như công viên địa chất. Hang động trong đá trầm tích, đặc biệt trong vùng karst ở Việt Nam rất đa dạng, luôn tạo ra những kỷ lục mới về chiều dài, độ sâu và sự phân bố trong khu vực và

trên thế giới. Trong khi đó, các hang động trong đá bazan ở Việt Nam mới được phát hiện vào năm 2007 ở khu vực thác Trinh Nữ, huyện Krông Nô, tỉnh Đắk Nông. Khu vực thác Trinh Nữ là một tổng thể di sản hấp dẫn ở cả hai khía cạnh tự nhiên và văn hóa xã hội. Nó bao gồm 3 thác nước và các thắng cảnh liên quan nổi tiếng ở Tây Nguyên, các miệng núi lửa, bazan dạng cột, sự xuất lộ suối ngầm, rừng nguyên sinh, di tích lịch sử văn hóa quốc gia,... Hang động ở đây khá nhiều và thường kéo dài theo hướng nhất định. Phân theo chiều sâu và mực nước ngầm, hang động có 2 loại: hang động khô và hang động ướt. Phần lớn hang động có đường kính 3-6m, cũng có một số hang trên 10m, chiều dài có thể đến vài trăm mét. Trên các bức tường và trần của một vài hang động, quan sát rõ được dấu vết dòng chảy rôi của dung nham. Đa số hang động là nơi nhiều dơi cư trú. Bên trong hang động ẩn chứa nhiều vấn đề lý thú về khảo cổ, sinh vật và địa chất chưa được khám phá. Hệ thống hang động này tạo ra một di sản địa học phong phú và độc đáo ở khu vực thác Trinh Nữ. Đây sẽ là điểm nhấn về du lịch nếu được nghiên cứu, khôi phục và đưa vào phát triển du lịch địa học.